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# CBO MEMORANDUM

AN ECONOMIC MODEL FOR
LONG-RUN BUDGET SIMULATIONS

July 1997

**CONGRESSIONAL BUDGET OFFICE**
**SECOND AND D STREETS, S.W.**
**WASHINGTON, D.C. 20515**

NOTES

Unless otherwise indicated, the years referred to in this memorandum are calendar years.

Numbers in the text and tables may not sum to totals because of rounding.

This memorandum describes the model that the Congressional Budget Office (CBO) developed to study budget issues in the long run. CBO used simulations from that model in preparing its March 1997 report *Long-Term Budgetary Pressures and Policy Options*.

John Sturrock of CBO's Macroeconomic Analysis Division wrote the memorandum under the supervision of Robert Dennis and Douglas Hamilton. Kenneth Fears provided able research assistance. Benjamin Page made valuable comments, as did Robert Arnold, Arlene Holen, Kent Smetters, and Ralph Smith. Christian Spoor edited the manuscript, Verlinda Lewis Harris typed earlier drafts, and Dorothy J. Kornegay prepared the final version for publication.

Some of the data used in the model and described in the memorandum were generously provided by two groups of scholars: Alan J. Auerbach of the University of California at Berkeley, Jagadeesh Gokhale of the Federal Reserve Bank of Cleveland, and Laurence J. Kotlikoff of Boston University; and Ronald D. Lee of the University of California at Berkeley and Shripad Tuljapurkar of Stanford University. They are not responsible for how CBO used their data or for the conclusions that CBO reached.

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# SUMMARY AND INTRODUCTION

The federal budget will face intense pressure in coming decades as health care costs mount and members of the baby-boom generation retire. Costs for Medicare and Medicaid are expected to grow much faster than federal revenues through at least 2020. And between now and 2030, the elderly population will more than double, while the number of workers will grow by only one-quarter. That demographic transition will expand the ratio of retirees to workers by more than half and drive up federal spending for Social Security and health care. Under those conditions, federal deficits could mushroom.

Such demographic and budgetary events would retard the growth of economic output by slowing the growth of two of its main determinants: labor and capital. With aging workers headed for retirement and projected fertility rates at near-record lows, the growth of the workforce will slow to a crawl. Furthermore, government deficits crowd out private investment, so persistent deficits would lead to less capital and lower output and hence to less revenue and even higher deficits. The interaction between the budget and the economy could start a cycle of ever-higher deficits and ever-slower growth.

Of course, that outcome is not foreordained. Much depends on uncertain economic and demographic events many years in the future. More important, the Congress can choose a policy to avoid a high-deficit/slow-growth cycle.

Without change, however, current policy will lead to ever-growing deficits, according to several analyses.[1] Most recently, the Congressional Budget Office (CBO) reported that under a wide range of conditions, current policy is unsustainable—it will eventually lead to surging deficits and falling living standards.[2] The outlook would improve if the Congress adheres to the current budget resolution, which calls for a balanced budget in 2002, but the deficit will rise after that unless the Congress resolves the long-term problems posed by growing health care costs and an aging population.

That conclusion comes from a model that CBO developed to study long-run budget issues. The model contains equations that account for the chief feedbacks between the budget and the economy. Those equations trace the way in which output depends on capital and labor and hence on the budget and population. In the model,

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1. General Accounting Office, *Budget Policy: Prompt Action Necessary to Avert Long-Term Damage to the Economy* (June 1992), and *The Deficit and the Economy: An Update of Long-Term Simulations* (April 1995); Office of Management and Budget, *Budget of the United States Government, Fiscal Year 1998: Analytical Perspectives* (February 1997), pp. 24-30; and Bipartisan Commission on Entitlement and Tax Reform, *Final Report to the President* (January 1995).

2. Congressional Budget Office, *Long-Term Budgetary Pressures and Policy Options* (March 1997), and *The Economic and Budget Outlook: Fiscal Years 1997-2006* (May 1996), Chapter 4.

the level of federal revenues and outlays depends on how CBO specifies those equations and on other assumptions about the economy, population, and long-run budget policy.

Assumptions about long-run policy are needed because current law defines such policy only for some federal programs. The mandatory provisions of most social insurance programs—such as Medicare, Social Security, and federal retirement—describe how spending for each qualified person depends on economic factors, such as prices or earnings history. The trustees of the insurance funds for those programs project long-run spending under current law, given their economic assumptions. For such mandatory programs, CBO calibrates its model to the official spending projections and then adjusts those projections to correspond to its own economic specifications and assumptions.

For other mandatory spending, however, the definition of long-run budget policy is ambiguous. For example, provisions of some income-support programs would allow them to shrink in real (inflation-adjusted) terms or even to expire. In the past, however, the Congress has changed or extended those programs to keep overall growth of such spending roughly in line with growth of the economy and of the number of recipients. CBO relies on historical relationships to make assumptions about how spending for such mandatory programs relates to the economy and population.

As for taxes, under current law, growth in real income per capita would push people into higher tax brackets, raising the effective tax rate. CBO assumes, however, that in the long run the Congress will keep the effective tax rate constant.

For discretionary spending, current law sets annual appropriations and gives no guide to long-run policy. Consequently, CBO explores the implications of two illustrative assumptions that appear to cover most reasonable possibilities. Those assumptions would fix discretionary spending in the long run either in constant dollars or as a share of output.

In addition to ambiguity about how to define long-run policy, analysis must also allow for uncertainty. Uncertainty afflicts the equations in the model, which determine such variables as output and interest rates. Uncertainty also plagues assumptions about other factors, such as population, that are determined outside the model. A model simulation grows more uncertain both as it extends farther into the future and as simulated variables—such as the ratio of the deficit to output—stray farther from their historical ranges.

CBO addressed some sources of uncertainty informally. For instance, in choosing numerical values to specify relationships, it tried to use plausibly optimistic

values—that is, values that reduce the chance of runaway deficits. Therefore, its qualitative conclusion that current policy is unsustainable should be more certain than any particular quantitative estimate.

CBO used more formal means to gauge the uncertainty arising from assumptions about population and productivity. Those factors are major sources of uncertainty in the budget because they largely determine output: population because it determines the number of people of working age; and productivity because, together with capital, it determines the output each worker produces. Moreover, the age of the population strongly affects spending for many social insurance programs. CBO estimated the effects that uncertainty about population and productivity has on the results by applying statistical analysis.

Such analysis supports the model's main conclusion that current policy is unsustainable. That conclusion stands up to a wide range of conditions and agrees with the findings of other analysts. Nevertheless, ambiguity about policy and uncertainty about other factors make precise predictions impossible.

Moreover, the model and methods are subject to refinement, and CBO continues to work on them. The effort described in this memorandum is merely CBO's first approach to modeling the economy and the federal budget in the long run and to estimating the effects of uncertainty about future population and productivity.

## MODELING THE ECONOMY

CBO represents the economy with an annual growth model—that is, a set of equations that specify interactions among variables such as output, investment, and interest rates.[3] For given assumptions about policy and for variables (such as population) that are determined outside the model, the equations simulate a path of the economy. Most equations are quite simple. No one can hope to portray the economy in detail, and CBO tries to model only the main interactions among variables in the long run.

The model includes behavioral equations that represent how people or governments respond to economic and demographic conditions. For example, equations describe how the interest rate depends on the supply of capital or how government spending depends on prices. Typically, the behavioral equation for an

3. Many of the economic features of the model were adapted from that of Henry J. Aaron, Barry P. Bosworth, and Gary T. Burtless, "Final Report to the Social Security Administration, U.S. Department of Health and Human Services, on Contract No. 600-87-0072 to the Brookings Institution" (1988).

economic variable specifies its year-to-year movement, either by its rate of change or by its change in level.

The model also includes identities—that is, equations that make behavioral variables satisfy accounting relationships. For instance, total output must equal private output plus public output. When applicable, identities in the model follow the current conventions of the official national income and product accounts (NIPAs).

Given the equations, the model needs two other factors to make a simulation: budget rules that define policy, and assumptions for exogenous variables (variables that are determined outside the model). With such rules and assumptions, the equations solve for simulated values of the variables in the model. A simulation does not predict what will happen, only what would happen under a given set of budget rules and assumptions for the exogenous variables. Thus, simulations provide a way to evaluate current budget policy and compare it with other policies.

To establish benchmarks for comparing budget policies, CBO generates base simulations under two sets of budget rules (described in a later section). The two sets of rules allow for a reasonable range of definitions for long-run budget policy.

For the most important exogenous variables, CBO assumes in a base simulation that:

- Population follows the midpath projection of the Social Security Administration (SSA);[4] and

- Total factor productivity (TFP) matches CBO's baseline economic projections through 2007 and then grows at 1 percent a year.[5] (Growth of TFP is the growth of output that cannot be accounted for by the growth of capital and labor.)

Given budget rules and assumptions for exogenous variables, CBO makes a base simulation of the model in two parts: through 2007 and beyond 2007. For the years through 2007, the behavioral equations are adjusted to make the simulated variables match their values in CBO's 10-year baseline projections. Such adjustments are needed because those projections embody detailed information about the budget and

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4. Social Security Administration, *The Annual Report of the Board of Trustees of the Old-Age and Survivors' Insurance and Disability Insurance Trust Fund* (June 1996).

5. The 10-year baseline economic and budget projections appear in Congressional Budget Office, *The Economic and Budget Outlook: Fiscal Years 1998-2007* (January 1997).

economy through the medium term, whereas the model only specifies broad relationships in the long run.

The adjustments work in a simple way. For example, the equation for real farm output specifies that such output grows at the same rate as real nonfarm, nonhousing business output. That equation simulates an unadjusted growth rate of 4.9 percent in 1999, whereas CBO's 10-year baseline projections assume a growth rate of 4.5 percent. So the adjustment for 1999 subtracts 0.4 percentage points from the unadjusted value. In other words, in 1999 the adjusted equation for the growth rate (%CH) of real farm output is given by:

%CH(real farm output) = %CH(real nonfarm, nonhousing business output) - 0.4

The model contains similar adjustments to each behavioral equation for each year through 2007.

For the second part of the simulation, the years after 2007, CBO imposes no adjustments on the economic equations. Real farm output after 2007 will grow in the model at the same rate as real nonfarm, nonhousing business output. Because the model imposes adjustments through 2007 but not after that, a base simulation matches CBO's baseline projections and then extends them according to the equations of the model.

A base simulation also serves as a reference for other simulations that use the same budget rules but different assumptions for exogenous variables. In such alternative simulations, each equation keeps the adjustments it needs to match CBO's baseline projections through 2007. Thus, for an alternative simulation, the adjustment also subtracts 0.4 percentage points in 1999 from the unadjusted value for the growth rate of real farm output. Because the same number is subtracted in each case, the adjustment does not affect the difference in the growth rate between a base simulation and alternative simulations. Instead, any differences arise entirely from differences in the growth rate of real nonfarm, nonhousing business output, as the unadjusted equation specifies.

As in most growth models, resources are assumed to be fully employed; the model thereby emphasizes the supply of factors of production. Output depends on the supply of capital and labor, which the model allocates among its production sectors. The supply of capital is determined by national saving and net capital flows from abroad; the supply of labor, by the size and composition of the population. The demands for capital and labor are defined by the model's assumed production relation; that relation, together with input supplies, determines interest and wage rates. After 2007, the overall price level is assumed to grow at a constant rate. Incomes and the private components of total demand (consumption, investment, and

net exports) are computed from identities. The public component (government consumption and investment) is modeled as part of government outlays.

Production

CBO's model has five production sectors:

- o Nonfarm, nonhousing businesses, which use capital and labor to produce goods and services;
- o Farms, which use capital and labor to produce farm goods;
- o Housing (including owner-occupied housing), which uses the stock of housing alone to produce housing services;
- o Households in the market (mainly people who work for nonprofit enterprise), who use labor alone to produce services; and
- o Governments, which use public capital and the labor of government workers to produce public services.

Nonfarm, Nonhousing Business. The nonfarm, nonhousing business sector—which accounts for about 80 percent of gross domestic product—forms the core of the model. CBO assumes that the sector produces output according to a Cobb-Douglas production relation. That is, the annual growth rate (%CH) of the sector's real output depends on the growth rates of its real capital, labor hours, and total factor productivity:

$$\%CH(\text{real output}) = 0.3*[\%CH(\text{real capital})] + 0.7*[\%CH(\text{labor hours})] + \%CH(\text{total factor productivity}).$$

The equation reflects historical relationships. The weights accorded to capital and labor represent their approximate shares of the sector's income: capital receives about 30 percent of the sector's gross income; labor, including the imputed labor of proprietors, receives about 70 percent. The assumption of a Cobb-Douglas production relation implies that those shares remain constant in the model.

The model aggregates the projected real capital in the sector with a Cobb-Douglas index that combines computers, other equipment, structures, and inventory. That index applies a weight of 0.05 to computers, 0.57 to other equipment, 0.31 to

structures, and 0.07 to inventories. The weights reflect estimated cost shares for the use of each type of capital.

Given labor hours and the real capital index, the historical growth of total factor productivity is calculated as a residual from the equation for real output.

Other Production Sectors. The model uses simple relations to determine the output of other production sectors:

- o Real farm output grows at the same rate as real output of the nonfarm, nonhousing business sector.
- o Real housing services grow at the same rate as the product of the real stock of housing and the effective real price of housing services (explained below).
- o Real household output grows at the same rate as real private labor compensation.
- o Real government output—federal plus state and local—equals the real compensation of government workers plus the real depreciation of public capital.

Private Capital and Labor

Private capital and labor are allocated to sectors according to supply and demand. In other words, the model assumes that (adjusted for risk and skill) capital and workers earn the same return or wage in every sector in which they are employed.

Investment and Capital. Private domestic investment represents an addition to the stock of private capital. The model allocates such investment as inventory, as housing, or as equipment and structures in the farm and the nonfarm, nonhousing business sectors. The real stock of inventory in the model grows at the same rate as real nonfarm, nonhousing business output.

Investment in housing is specified by assuming that the demand for real housing services obeys a Cobb-Douglas relation. Consequently, if the real price of housing services rises by 1 percent, the quantity demanded as a share of real consumption falls by 1 percent (so real housing services remain a constant share of real consumption). The real price of housing services moves with the real interest rate, but not point for point, because the cost of depreciation and the tax advantage of owning a home also figure in the price. Moreover, the model smooths the response

of housing demand to changes in price by specifying that the effective real price of housing services depends on the average real interest rate in the current year and the past nine years. For a given effective real price, investment each year in the model adds enough to the housing stock that it can generate the services demanded at that price. That is, supply equals demand in the market for housing services.

Other forms of investment are determined as a residual from an identity: namely, that private domestic investment (other than for housing and inventory) equals national saving plus net capital flows from abroad minus gross investment in housing, inventory, and government capital. (The identity also adds a statistical discrepancy that reconciles any difference between measured output and income, which ideally are equal.) The residual is allocated by assuming that real investment in the farm sector remains a constant fraction of real fixed investment in the nonhousing business sectors. The model then assigns the balance of investment to the nonfarm, nonhousing business sector, assuming that after 2007 the nominal shares of that sector's investment in structures, computers, and other equipment remain fixed. A simulation stops if gross investment in that sector turns negative.

Stocks of capital are cumulated each year by using the perpetual inventory method. That is, the real stock of each type of capital in each sector at the end of the year equals real investment in that capital during the year plus the stock at the end of the previous year minus its depreciation during the year.

Labor. The total supply of labor hours in the model depends on the size of the population and its composition by age and sex. Composition matters because, for example, the average 40-year-old man works more hours in a year than does the average 60-year-old man. Therefore, other things being equal, total hours fall if the number of 40-year-old men falls and the number of 60-year-old men rises by the same amount.

CBO simulates total hours by computing an exogenous index. For a base case, the index depends on SSA's midpath projection of the population by age and sex and assumes that the number of hours worked in a year by the average man or woman of each age remains constant.[6] The model then applies multiplicative factors to the base index through 2007 so that the growth of the index matches the growth of hours in CBO's baseline economic projections. The factor for any year multiplies the index by (approximately) 1.01 for every 1 percentage point that the unadjusted growth rate of the index falls short of the growth rate of total hours in the baseline projections. That method prorates the discrepancy between the baseline projections and the

6. CBO used data from the Bureau of Labor Statistics (BLS) on labor force participation and hours worked in 1996. Because of the importance of an aging population, CBO used unpublished BLS data to separate men and women age 55 to 79 into 35 single-year age cohorts by sex.

unadjusted index, distributing the difference in total hours in proportion to the hours worked by people of each age and sex. After 2007, total hours grow without adjustment at the index's simulated rate. As the population ages in a base case, simulated growth of total hours declines, slowing to a crawl after 2015 (see Figure 1).

The model assumes that total hours in each nonfederal, nonhousing sector grow at an identical rate. That rate may vary from year to year, but total hours in each of those sectors grow at the same rate in any year.

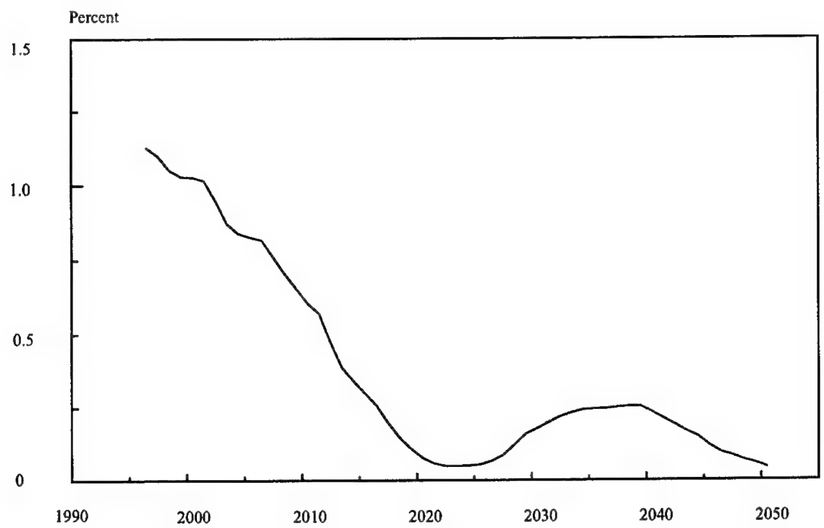
The way in which the model allocates total labor hours between the federal and nonfederal sectors depends on the budget rule for federal compensation. Federal compensation after 2007 may grow either at the rate of inflation or at the same rate as net national product. If federal compensation grows with net national product, total hours of federal workers grow at the same rate as total hours in the economy. But if federal compensation grows only at the rate of inflation, total hours of federal workers grow more slowly than total hours in the economy. The model prorates that shortfall in federal hours among the nonfederal, nonhousing sectors.

The model also adjusts those prorated hours to allow for the higher-than-average productivity of federal workers. The current hourly compensation of such workers is about 20 percent higher than that of their nonfederal counterparts. CBO assumes that the difference in pay reflects skills that federal workers would carry with them if they left the federal sector. To allow for that difference, the model multiplies by 1.2 the prorated hours of workers who would otherwise be in the federal sector, thereby keeping track of their hours of effective labor. When the model prorates the hours of federal workers to the nonfarm, nonhousing business sector, it is their effective-labor hours that appear in the production relation. That method keeps productivity consistent in the model and makes the hourly wage of all workers grow at the same rate.

Nonfederal National Saving

Domestic funds for investment come from national saving, which consists of private saving (personal and business) plus budget surpluses at all levels of government —federal, state, and local. Typically, state and local governments run surpluses and the federal government runs deficits. (The federal budget is discussed in a later section.) Because national saving finances both public and private investment, domestic saving available for private investment equals private saving minus government deficits and net government investment. To indicate domestic saving

FIGURE 1. SIMULATED ANNUAL GROWTH OF TOTAL LABOR HOURS




SOURCE: Congressional Budget Office based on data from the Department of Labor, Bureau of Labor Statistics; and the Social Security Administration.

available for private investment, CBO's model uses the concepts of adjusted national saving (national saving minus net government investment) and the adjusted deficit (government deficits plus net government investment). Those concepts correspond to the definitions of national saving and the deficit that the Department of Commerce used before 1996, when it changed the benchmark of the NIPAs.

Private Saving. The model specifies that private saving equals the sum of two components: an exogenous fraction of gross national product and one-half of the adjusted deficit. Through 2007, CBO chooses that exogenous fraction so that the equation for private saving matches its values in the 10-year baseline projections. The fraction equals about 15 percent in 2007 and remains at that rate thereafter.

In accord with recent studies, private saving in the model also depends on changes in the adjusted deficit.[7] Part of that change in saving may represent a direct response by so-called Ricardian consumers. When the adjusted deficit rises, Ricardian consumers save more to ensure that they or their descendants can pay the higher future taxes that the higher adjusted deficit implies.[8] If all consumers were Ricardian, the adjusted deficit would not affect adjusted national saving; instead, private saving would move to fully offset any change in the adjusted deficit.

The specification of private saving in the model also represents an indirect response to the higher adjusted deficit. That response occurs because the adjusted deficit displaces private investment and leads to higher interest rates and higher interest payments by government. Higher interest rates raise the rate of return on saving and reduce the value of existing assets. Higher interest payments to holders of Treasury securities raise disposable income as a share of output. Taken together, higher interest rates, lower asset values, and higher disposable income encourage everyone to save more.

State and Local Government Saving. The model assumes that budget surpluses of state and local governments slowly converge to zero: each year's total surplus is 98 percent of the previous year's. Revenues are the surplus plus outlays. The outlays of state and local governments are determined by behavioral equations, specifically:

7. See Paul R. Masson, Tamin Bayoumi, and Hossein Samei, *International Evidence on the Determinants of Private Saving*, Working Paper No. 95/51 (Washington, D.C.: International Monetary Fund, May 1995); and Sebastian Edwards, *Why Are Saving Rates So Different Across Countries? An International Comparative Analysis*, Working Paper No. 5097 (Cambridge, Mass.: National Bureau of Economic Research, April 1995).

8. See Robert R. Barro, "Are Government Bonds Net Worth?" *Journal of Political Economy*, vol. 82, no. 6 (November/December 1974), pp. 1095-1117.

- Medicaid spending grows at the same rate as federal spending for that program.

- Spending for retirement benefits grows at the same rate as federal spending for civilian retirees.

- Other transfers, such as workers' compensation or aid to low-income families, grow at the same rate as net national product.

- Consumption expenditures (other than depreciation of capital) and gross investment in tangible assets grow at the same rate as net national product.

- Depreciation depends on the stock of state and local capital and its depreciation rate.

- Net interest payments, minus dividends received, depend on interest rates and the stock of state and local debt. The model assumes that 20 percent of such debt matures each year and that the part that is not retired is reissued at the current average interest rate for such securities.

### Net International Capital, Income, and Trade Flows

When national saving falls, domestic investment need not fall by the same amount. Instead, the country may reduce its net lending abroad, either by lending less or by borrowing more. A drop in such net lending appears as a decline in the flow of net foreign investment (mostly U.S. investment abroad minus foreign investment in the United States).

A decrease in the flow of net foreign investment (NFI) has further consequences. The lower flow cumulates into a lower net international investment position (which is the value of foreign assets held by U.S. investors minus the value of U.S. assets held by foreigners). A lower net international investment position leads in turn to lower net service factor income (which is mainly income earned by U.S. investments abroad minus income paid on foreign investments in the United States). Other things being equal, a decrease in the flow of NFI also corresponds to a decline in the flow of net exports.

Furthermore, when a higher deficit leads to less net foreign investment (other things being equal), that in turn prompts a higher exchange rate in the short run and a lower exchange rate in the long run. (The exchange rate measures the units of foreign currency that a dollar can buy.) However, CBO's model does not include an equation for the exchange rate.

The model's treatment of NFI and its exclusion of the exchange rate make it too optimistic about growing deficits in the long run. Because the model ignores constraints that international trade and borrowing must eventually satisfy, domestic output and purchasing power in a base simulation remain higher in the long run than could be the case.

Net Foreign Investment. In the model, NFI depends on two components: a reference level and the change in the adjusted national saving rate (adjusted national saving as a share of net national product). The reference level depends on the previous year's level of net foreign investment and would determine NFI in the absence of a change in the adjusted national saving rate. Through 2007, the reference level grows from the previous year's level of NFI at the same rate as net national product (NNP). After 2007, the reference level is simply the previous year's level of net foreign investment. If the adjusted national saving rate stabilizes, simulated net foreign investment as a share of output eventually approaches zero.

If the adjusted national saving rate falls, however, the model assumes that net foreign investment will fall from its reference level (REF). Specifically, NFI falls from its reference level by 40 percent of the amount by which adjusted national saving (ANS) falls short of maintaining its previous year's share of net national product. That is,

$$NFI/NNP = REF/NNP + 0.4*[(ANS/NNP) - (ANS_{-1}/NNP_{-1})],$$

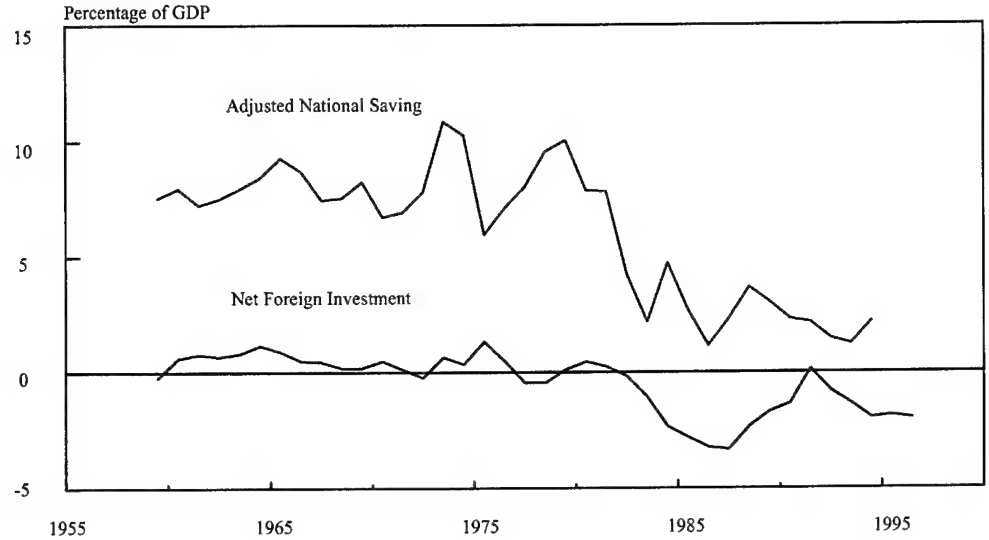
where a subscript indicates the previous year's value. As a result, a shortfall in adjusted national saving reduces private domestic investment by only 60 percent as much. Of course, if the adjusted national saving rate rises, an increase in net foreign investment dampens the increase in domestic investment.

The 40 percent estimate is roughly consistent with events during the 1980s, when a sharp decline in adjusted national saving led to a substantial decline in net foreign investment (see Figure 2).[9] Net foreign investment has been negative —indicating net borrowing from abroad—in every year but one since 1982.

But an offset of 40 percent cannot persist in the long run under current policy. If simulated deficits rose continually as a share of output, the simulated share of net borrowing from abroad would also rise continually. In fact, neither net borrowing from abroad nor government deficits can rise forever as a share of output. Thus, the assumed response of net foreign investment is optimistic because capital inflows in

9. See Martin Feldstein and Phillipe Bacchetta, "National Saving and International Investment," in B. Douglas Bernheim and John B. Shoven, eds., *National Saving and Economic Performance* (Chicago: University of Chicago Press, 1991), pp. 201-220.

FIGURE 2. NET FOREIGN INVESTMENT AND ADJUSTED NATIONAL SAVING




SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of Economic Analysis.

NOTE: Adjusted national saving is national saving minus net government investment.

the model keep long-run domestic output higher than could be sustained in the face of ever-rising deficits.

Net International Investment Position. The net international investment position is calculated by cumulating net foreign investment. CBO's model assumes that foreign assets held by U.S. investors grow at the same rate as net national product; foreign holdings of U.S. assets are computed as a residual.

Net Service Factor Income. For a given net international investment position, net service factor income depends primarily on the rates of return on investment at home and abroad. The model assumes that in an integrated global economy, those real rates of return move in tandem. Hence, in the model, real rates of return on U.S.-owned foreign assets and foreign-owned U.S. assets move point for point with the real interest rate in the United States. That assumption preserves the current difference in international rates of return: U.S.-owned foreign assets in 1994 earned over 1 percentage point more than foreign-owned U.S. assets (see Figure 3).

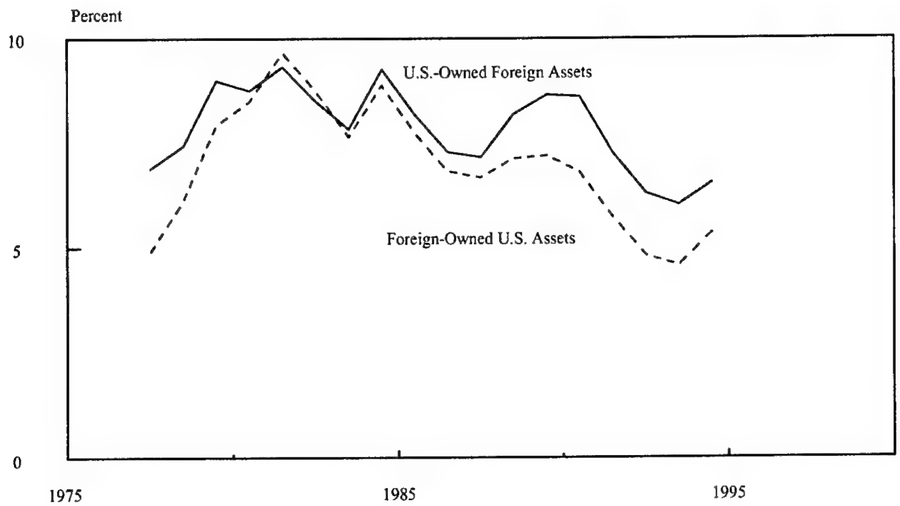
Net Exports. The model determines net exports by an identity: they equal net foreign investment minus net service factor income plus business, personal, and government transfers to the rest of the world. Foreign transfers by the private sector grow in the model at the same rate as net national product; foreign transfers by the government depend on the budget rule for discretionary spending.

Exchange Rate. Because the model does not have an equation for the exchange rate, it does not link the dollar to net borrowing from abroad. Instead, the exchange rate implicitly matches its values in CBO's 10-year baseline projections and remains at its 2007 level thereafter.

In fact, the exchange rate would respond to a change in the rate of net borrowing from abroad. In the short run, more borrowing causes the dollar to rise, reducing the dollar price of imports and allowing U.S. citizens to enjoy a higher standard of living. But net borrowing now has to be financed by net exports later. To induce those net exports, the dollar has to fall below its original value, raising the dollar price of imports above its original level.

Thus, excluding the exchange rate makes a base case too optimistic in the long run. Because the model ignores changes in the terms of trade, it overstates the long-run value of the dollar and the U.S. command of resources.

FIGURE 3. INTERNATIONAL RATES OF RETURN




SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of Economic Analysis.

NOTES: The rate of return on U.S.-owned foreign assets is estimated as receipts of factor income as a percentage of the market value of U.S.-owned foreign assets.

The rate of return on foreign-owned U.S. assets is estimated as payments of factor income as a percentage of the market value of foreign-owned U.S. assets.

Interest Rates, Wage Rates, and Prices

Competition is assumed to make interest rates, wage rates, and prices correspond to production relations. In other words, supply equals demand in the markets for capital, labor, and output, and no sellers receive monopoly profits. Capital and labor stay fully employed and earn the same real interest and wage rates (adjusted for risk and skill) in all of the sectors that use them. The price index for gross domestic product is determined by assumptions outside the model, and the prices of component goods and services are determined consistently within the model.

Interest Rates. The real rate of return on capital in the nonfarm, nonhousing business sector serves as the key interest rate in the model. The model assumes that competition for funds in the long run makes all interest rates move point for point with a change in the real rate of return on capital.

That return is given by the ratio of the sector's net capital earnings to the total value of its equipment, structures, and inventory. Aside from minor items, net capital earnings are gross payments to capital minus depreciation and indirect and corporate taxes. According to the assumed Cobb-Douglas production relation, gross payments to capital in the model make up 30 percent of the output of the nonfarm, nonhousing business sector.

As government debt displaces private capital, the rate of return on capital rises. Because changes in output and in capital and labor incomes are determined by the production relation, the rise is just enough for firms to want to hold each year's existing stock of capital, assuming that people are myopic—in other words, that they expect the rate of return to remain at its current level.

The assumption of myopia implies that long-term interest rates do not satisfy the so-called expectations hypothesis. That is, the model does not equate the current long-term interest rate to a risk premium plus a weighted average of simulated short-term rates. Such an equality would hold, for example, if buyers of 10-year bonds earned as much on average (adjusted for risk) as they would if they bought and reinvested one-year bills for 10 years.

Given base simulations of federal debt, the model is more optimistic than it would be if it satisfied the expectations hypothesis. If the model assumed that people were forward-looking rather than myopic, long-term rates would climb much faster than they do because investors would anticipate further increases in short-term rates as debt mounted in relation to output. A faster rise in long-term rates would raise interest payments on the debt more than otherwise and would make the economic and budget situation much worse. In fact, with the debt-to-output ratio rising indefinitely

under current policy, forward-looking agents would foresee economic collapse, and the model could not be solved.

Wage Rates. Like interest rates, wage rates are determined from the production relation and the supply of capital and labor in the nonfarm, nonhousing business sector. The assumed Cobb-Douglas production relation for that sector implies that labor compensation equals 70 percent of output. Thus, the growth rate of hourly compensation is the growth rate of compensation minus the growth rate of effective-labor hours (which adjust for the higher productivity of those workers who would otherwise be in the federal sector when the budget rule has federal compensation growing only at the rate of inflation). Compensation, wages, and fringe benefits are all assumed to increase at the same rate, so the hourly wage increases at the same rate as hourly compensation. The model assumes that both hourly compensation and the wage rate grow in all nonhousing sectors at their rate in the nonfarm, nonhousing business sector.

Prices. The overall price level, which is assumed to increase in the long run at 2.7 percent a year, is measured by the price index for GDP (gross domestic product). The model constructs that price measure as a chain Laspeyres index, which equals the sum of the prices of GDP components weighted by their shares of the previous year's GDP.[10] Thus, the index depends on the mix of components that make up output as well as on their prices.

That mix changes over time, and the prices of components do not all grow at the same rate. In particular, computers' share of GDP has risen in the past 35 years while their price has fallen sharply. CBO assumes that their price will continue to decline rapidly for the next 10 years. Beyond then, CBO assumes that the rate of price decline will gradually abate until, by 2020 and thereafter, the price of computers grows at the same rate as other prices in the nonhousing business sectors. Because the model fixes computers' nominal share of investment in the nonfarm, nonhousing business sector, the real share remains stable after 2020.

Prices in some other sectors of the model also grow at rates that differ from the rate in the (noncomputer) nonhousing business sectors. First, the price of housing services depends on the price of housing, the interest rate, and other factors. Even if the price of housing increases at the same rate as other prices, the price of housing services increases faster when the interest rate rises. Second, the recorded prices of household and government output depend on those sectors' wage rates, which grow in the model with the wage rate in the business sector.

10. The chain Laspeyres index closely approximates the Fisher index that the Department of Commerce uses to calculate the GDP price index.

Taking those factors into account, the model solves for the prices of computers, housing services, and household and government output. CBO assumes that component prices in the remaining sectors—farm and nonfarm, nonhousing business other than computers—grow at the same rate. That rate need not be constant from year to year, but the price of each component (such as consumer goods or business inventory) grows at the same rate in any year. The model finds the rate each year that makes the resulting prices and quantities in all sectors correspond to the overall price level.

The model does not explicitly deal with private-sector health care costs or the price of medical services. Although simulations show spending by age and sex for Medicare and Medicaid growing faster than output, CBO does not judge whether higher medical costs stem from higher prices or better care.

Incomes and the Components of Total Demand

For given output, factor supplies, and wage and interest rates, the model determines incomes by identities of the national income and product accounts. For elements of the identities not discussed elsewhere, CBO assumes that:

- Interest paid by consumers to business grows at the same rate as personal consumption.
- The statistical discrepancy between measured output and income slowly converges to zero.
- Capital grants and wage and salary accruals minus disbursements are zero.
- Other minor elements grow at the same rate as net national product.

The components of total demand that are not modeled directly also come from identities. Personal consumption equals disposable personal income minus three things: personal saving, interest paid by consumers to business, and net personal transfer payments to foreigners. Net exports, private domestic investment, and state and local consumption and investment have already been discussed. Federal consumption and investment are described in the next section.

The budget part of CBO's model determines the expenditures and receipts that make up the change in federal debt held by the public. Most expenditures in the model are defined by their functions in the national income and product accounts. (Some NIPA definitions differ from those of the unified budget, which is the focus of CBO's annual economic and budget reports.) Federal expenditures in the NIPAs consist of transfers, grants, and net subsidies; consumption expenditures; and net interest (see Table 1).

Transfers, grants, and net subsidies are payments for which the government does not receive a current good or service. Specifically, they are transfer payments to persons, grants to state and local governments, transfers to the rest of the world, and net subsidies to business. General transfers to persons serve as part of the social safety net; this category comprises unemployment insurance, food stamps, the earned income tax credit, Supplemental Security Income, and other programs.[11] The largest portion of federal transfers to persons, however, is transfer payments for social insurance—especially for Medicare and Social Security. Additional transfer payments go for retirement and veterans' benefits, which represent compensation for past service. Of grants to state and local governments, over 40 percent pays for the federal share of Medicaid, which the model treats as part of health care. Other grants mainly include the federal share of funds for state and local construction and for transfer programs administered locally, such as aid to low-income families. Transfers to the rest of the world are mostly foreign aid. Net subsidies are subsidies to business, such as housing assistance, minus the current surplus of government enterprises, such as the Postal Service.

Federal consumption expenditures represent the resources that the federal government uses during the year to provide public services, such as defense or airline safety. The NIPA definition of government consumption includes goods and services devoted to intangible investments, such as research, public health, or education. Thus, federal consumption comprises goods bought and used up during the year, compensation paid to federal workers, and depreciation of federal capital.

11. The other programs consist of pension benefit guaranty, veterans' life insurance, workers' compensation, military medical insurance, Black Lung benefits, direct relief, and a residual category that mainly includes payments for nonprofit institutions, student aid, and medical services for retired military personnel and their dependents at nonmilitary facilities.

Federal net interest consists of interest that the government pays—chiefly on debt held by the public—minus interest that it receives on federal loans.[12]

Receipts in the NIPAs are loosely called taxes. They consist of payroll, personal, corporate, and indirect (mostly excise) taxes, as well as personal nontax receipts, such as the premiums that Medicare beneficiaries pay for coverage under Part B (Supplementary Medical Insurance).

Subtracting receipts from expenditures gives the NIPA federal deficit. The deficit measures the decrease in net federal assets (tangible and financial assets minus financial liabilities) that results from fiscal operations in the 50 states and the District of Columbia. The NIPA deficit omits any change in the value of net assets that arises from other factors, such as a change in the value of oil deposits on public lands, or expenditures to and receipts from U.S. territories and possessions. Unlike the unified budget deficit, the NIPA deficit measures the change in net assets on an accrual, rather than a cash, basis. For example, taxes paid in either 1994 or 1995 on income earned in 1994 are credited to 1994 NIPA receipts.

Two major components separate the NIPA deficit from the unified deficit.[13] The first is federal net investment, which represents an increase in tangible federal assets, such as roads or buildings. That investment does not appear in the NIPA deficit because it does not change net federal assets. When the government invests, it exchanges one asset for another if it pays cash, or it increases both its assets and liabilities if it issues debt. In either case, the government's net assets remain the same. Net investment appears in the unified deficit because that deficit records federal cash transactions. The second component involves reconciliation items, which account for such differences between the NIPA and unified deficits as accrual versus cash accounting, net transactions with U.S. territories and possessions, and certain lending and financial transactions. Adding net investment and reconciliation items to the NIPA deficit yields the unified deficit (see Table 1).

Calculating the annual change in debt held by the public then requires subtracting other means of financing—means such as the minting of coins or the drawing down of the Treasury's cash balances. Other means of financing leave federal net assets and cash transactions unchanged but reduce the need to issue debt to the public. Debt issued to the public falls short of the unified deficit if the total for

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12. More technically, net interest is interest paid on Treasury debt plus other interest (interest paid on obligations other than Treasury debt minus interest received). Because more of other interest is received than paid, it is negative and reduces net interest. For a thorough discussion of federal interest costs, see Congressional Budget Office, *Federal Debt and Interest Costs* (May 1993).

13. See Congressional Budget Office, *The Economic and Budget Outlook: Fiscal Years 1998-2007*, pp. 97-101.

TABLE 1. ANNUAL CHANGE IN FEDERAL DEBT HELD BY THE PUBLIC, 1975-1996

| | 1975 | 1980 | 1985 | 1990 | 1995 | 1996 |
|---|---|---|---|---|---|---|
| **In Billions of Dollars** | | | | | | |
| NIPA Expenditures | | | | | | |
| Transfers, grants, and net subsidies | | | | | | |
| General transfers | 35 | 47 | 51 | 71 | 107 | 111 |
| Health care | | | | | | |
| Medicare | 16 | 36 | 70 | 108 | 180 | 197 |
| Medicaid (Federal share) | 8 | 14 | 23 | 43 | 89 | 93 |
| Social Security | 66 | 119 | 183 | 244 | 328 | 342 |
| Retirement and veterans' benefits | 31 | 46 | 62 | 77 | 94 | 98 |
| Other grants, foreign transfers, and net subsidies | 59 | 93 | 115 | 135 | 159 | 169 |
| Consumption expenditures | 135 | 215 | 343 | 427 | 454 | 459 |
| Net interest | 23 | 53 | 127 | 180 | 229 | 233 |
| Total | 372 | 623 | 974 | 1,285 | 1,640 | 1,702 |
| NIPA Receipts[a] | 297 | 562 | 811 | 1,130 | 1,478 | 1,575 |
| NIPA Deficit | 74 | 61 | 163 | 155 | 162 | 127 |
| Translation to Unified Deficit | | | | | | |
| Net investment[b] | -4 | c | 23 | 18 | -8 | -6 |
| Reconciliation items[d] | -26 | -2 | 21 | 64 | -7 | -11 |
| Total | -30 | -2 | 44 | 82 | -16 | -17 |
| Unified Deficit | 44 | 59 | 207 | 237 | 146 | 110 |
| Other Means of Financing | -42 | -18 | -19 | -10 | 2 | -35 |
| Change in Debt Held by the Public | 86 | 77 | 226 | 247 | 144 | 145 |

(Continued)

SOURCE: Congressional Budget Office based on data from the Office of Management and Budget; the Department of Commerce, Bureau of Economic Analysis; and the Federal Reserve Board.

NOTE: NIPA = national income and product accounts.

TABLE 1. CONTINUED

| | 1975 | 1980 | 1985 | 1990 | 1995 | 1996 |
|---|---|---|---|---|---|---|
| **As a Percentage of GDP** | | | | | | |
| NIPA Expenditures | | | | | | |
| Transfers, grants, and net subsidies | | | | | | |
| General transfers | 2 | 2 | 1 | 1 | 1 | 1 |
| Health care | | | | | | |
| Medicare | 1 | 1 | 2 | 2 | 2 | 3 |
| Medicaid (Federal share) | e | 1 | 1 | 1 | 1 | 1 |
| Social Security | 4 | 4 | 4 | 4 | 5 | 5 |
| Retirement and veterans' benefits | 2 | 2 | 1 | 1 | 1 | 1 |
| Other grants, foreign tranfers, and net subsidies | 4 | 3 | 3 | 2 | 2 | 2 |
| Consumption expenditures | 8 | 8 | 8 | 7 | 6 | 6 |
| Net interest | 1 | 2 | 3 | 3 | 3 | 3 |
| Total | 23 | 22 | 23 | 22 | 23 | 22 |
| NIPA Receipts[a] | 18 | 20 | 19 | 20 | 20 | 21 |
| NIPA Deficit | 5 | 2 | 4 | 3 | 2 | 2 |
| Translation to Unified Deficit | | | | | | |
| Net investment[b] | e | e | 1 | e | e | e |
| Reconciliation items[d] | -2 | e | 1 | 1 | e | e |
| Total | -2 | e | 1 | 1 | e | e |
| Unified Deficit | 3 | 2 | 5 | 4 | 2 | 1 |
| Other Means of Financing | -3 | -1 | e | e | e | e |
| Change in Debt Held by the Public | 5 | 3 | 5 | 4 | 2 | 2 |

a. Includes taxes and personal nontax revenues, such as licensing fees.

b. Gross federal investment minus consumption of federal capital.

c. Less than $0.5 billion in absolute value.

d. Includes items that account for differences arising from cash and accrual bases, expenditures to and receipts from U.S. territories and possessions, lending and financial transactions, and other activities.

e. Less than 0.5 percent in absolute value.

other means of financing is positive, but exceeds the unified deficit if that total is negative (as, for example, it may be when cash balances rise).

In CBO's model, federal expenditures and receipts are specified by budget equations that depend on a set of budget rules. The equations and rules determine the growth of budget components in a base simulation or in a simulation under alternative assumptions for population and total factor productivity.

### Making a Budget Simulation Under Base Assumptions

To allow for ambiguity about the definition of long-run budget policy, CBO makes two base simulations that use different rules for discretionary spending. Both rules assume that, subject to statutory caps, discretionary spending grows through 2007 at the inflation rate (the growth rate of the price level). After 2007, one rule assumes that such spending grows at the same rate as net national product—that is, at the rate of inflation plus the real rate of growth. The other rule assumes that discretionary spending grows at the rate of inflation alone. Taxes and mandatory spending follow other assumptions (described below), which remain the same under both rules.

The two rules appear to span a range more than large enough to include any reasonable definition of long-run policy. In the past 30 years, discretionary spending has grown an average of 1.8 percentage points faster than the price level and 1.6 percentage points slower than net national product. If discretionary outlays grew only at the rate of inflation, they would stay fixed in real terms and fall as a share of output even faster than they have in the past—an event that appears unlikely over the next half century. Instead, public demand for nondefense discretionary spending (such as for public works or education and training) may well increase as the population grows and incomes rise. Moreover, it may be optimistic to assume that the world will remain as peaceful as it is today and that the share of output devoted to defense will continue to decline.

Under either rule for discretionary spending, the budget part of the model makes a base simulation in two steps. For the years through 2007, the model adjusts the budget equations in such a way that when economic variables match CBO's baseline economic projections, budget variables match CBO's baseline budget projections. To adjust the budget equations, the model uses multiplicative factors like those used for total labor hours. Thus, other things being equal, disability payments to 40-year-old men would double if the number of 40-year-old men doubled. That method ensures that under alternative population assumptions (other things being equal) spending per person by age and sex would remain the same as in a base case.

For years after 2007, CBO calibrates the equations for programs whose long-run budget policy is spelled out in current law. The equations for those programs—Medicare, Social Security, civilian and military retirement, and Railroad Retirement—broadly describe the provisions of current law. The calibrations ensure that CBO's simulated spending for the programs is (approximately) consistent with current law, given the population projections that CBO uses and the economic variables that the model generates.

In the case of taxes and other spending after 2007, however, CBO does not assume that current law describes long-run policy for those variables. Instead, the model uses their unadjusted equations, which specify that the effective tax rate remains constant or that such spending will depend on the economy and population largely as it has in the past.

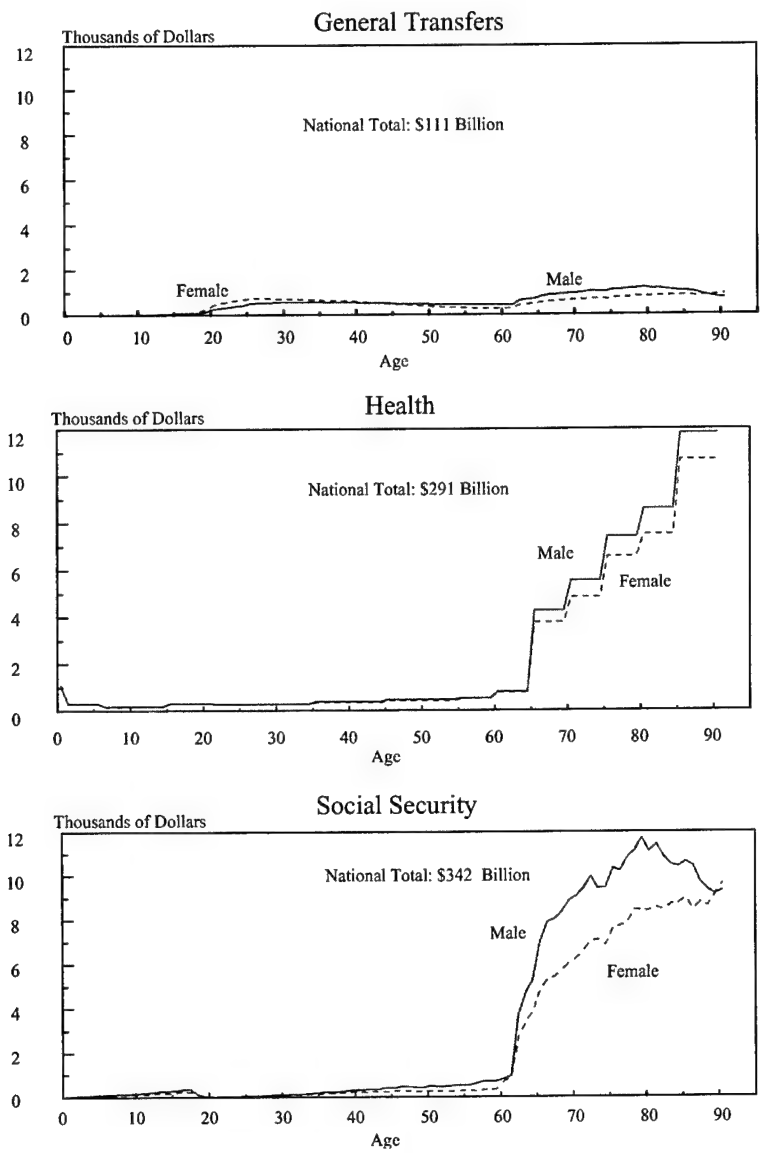
<u>Transfers, Grants, and Net Subsidies</u>. The model uses a variety of budget rules to specify transfers, grants, and net subsidies. The rules for general transfers relate such spending to population and nominal output per worker-hour. Unique features demand more complex rules for health care programs and Social Security, and limitations in data require special rules for retirement and veterans' benefits. The rules for other grants, foreign transfers, and net subsidies relate such spending to output.

*General Transfers*. For general transfers, the model uses the following rule: spending per person by age and sex grows at the same rate as net national product per worker-hour. The rule does not purport to represent current law or treat each program in detail; instead, it assumes that in the long run the Congress will make that part of the safety net grow in line with population and output. Without that assumption, such spending after 2007 would fall forever in real terms, although past policy has kept it at a roughly constant share of output.

Using that rule requires estimating how much is now paid by age and sex—that is, the current age/sex profile of general transfers (see Figure 4). An age/sex profile indicates spending for the average person, not the average beneficiary. Even if spending per beneficiary is high, spending per person may be low if there are relatively few beneficiaries. Such average payments can vary widely by age and sex—the average 30-year-old woman receives 134 percent as much in general transfers as the average 40-year-old man; the average 70-year-old man receives 184 percent as much. The model assumes that such ratios stay fixed.

General transfers are then simulated in two steps. For a base case, CBO first constructs an exogenous index that depends on the age/sex profile and on SSA's mid-

FIGURE 4. SELECTED FEDERAL TRANSFERS: ESTIMATED DISTRIBUTION OF BENEFITS PER PERSON IN 1996, BY AGE AND SEX




SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of Economic Analysis; the Department of Labor, Bureau of Labor Statistics; the Health Care Financing Administration; the Social Security Administration; and Alan J. Auerbach, Jagadeesh Gokhale, and Laurence J. Kotlikoff as described in "Restoring Generational Balance in U.S. Fiscal Policy: What Will It Take?" *Economic Review,* Federal Reserve Bank of Cleveland, vol. 31, no. 1 (First Quarter 1995), pp. 2-12.

NOTES: General transfers are payments for unemployment insurance, food stamps, the earned income tax credit, Supplemental Security Income, pension benefit guaranty, veterans' life insurance, workers' compensation, military medical insurance, Black Lung benefits, and a category that mainly includes payments for nonprofit institutions, student aid, and medical services for retired military personnel and their dependents at nonmilitary facilities.

Health care transfers are payments for Medicare and the federal share of Medicaid.

path projection of the population by age and sex. That index shows how such transfers would grow as the population grows and its composition changes, assuming that spending for the average male and female of every age remains constant.

In the second step, the model relates general transfers to productivity as well as demographics by making transfers increase at the growth rate of their index plus the growth rate of net national product per worker-hour (see Figure 5). For instance, if net national product per worker-hour grew at a hypothetical rate of 4.1 percent a year, the rule would make spending for general transfers grow at an average rate of 4.6 percent a year through 2050.[14] Such transfers would grow faster than output as the population aged, because payments to the average person increase slightly with age.

*Health Care.* For a base case, CBO also uses age/sex profiles and SSA's midpath population projection to construct exogenous indexes for Medicare and Medicaid —health care programs whose payments to the elderly rise sharply with age. But two additional factors apply to health care programs. First, spending per person by age and sex grows not with output per worker-hour but with medical costs per person. For the past 25 years, those costs have increased much faster than compensation per hour—the difference in growth rates is called the additional growth of medical costs per person. (See Table 2, which shows the difference for Medicare and Medicaid enrollees.) Despite that past rate of increase, CBO assumes for each program that additional growth of medical costs per person will slowly fall, reaching zero by 2020 and remaining there. After 2020, spending per person by age and sex would grow at the same rate as compensation per hour.

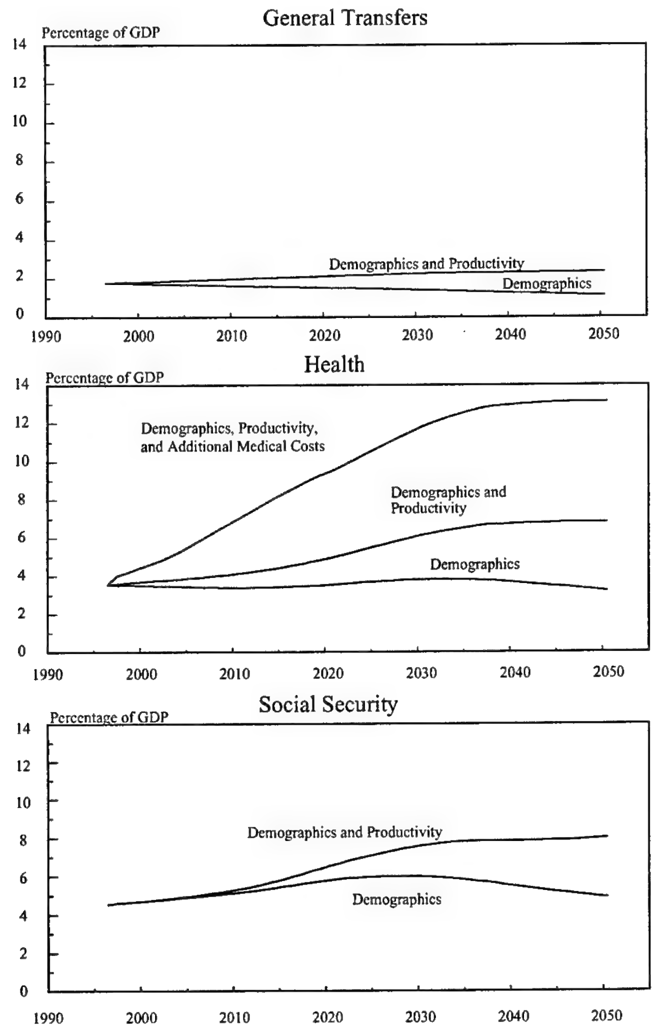
The Health Care Financing Administration (HCFA) uses a similar assumption for its 75-year projection of Medicare's Part A (Hospital Insurance).[15] Both CBO and HCFA adopt that assumption because medical costs per person cannot forever grow faster than compensation per hour, even though no explicit factor can be predicted to slow their growth in the absence of policy changes. Despite seemingly optimistic assumptions about additional medical costs, their growth through 2020 will combine with an aging population to accelerate federal spending for health care.

Second, CBO uses multiplicative factors after 2007 to calibrate Medicare spending to HCFA's projected rate. In other words, if the model's growth rates for economic variables after 2007 match HCFA's, then the growth rate for Medicare will

14. The figure of 4.1 percent reflects an assumed real growth rate of 1.4 percent and an inflation rate of 2.7 percent. That real growth rate results from dividing 1 percent (the base growth rate of total factor productivity) by 0.7 (labor's approximate share of gross output). The example assumes that net national product grows in a balanced economy at the same rate as gross domestic product.

15. Health Care Financing Administration, *The Annual Report of the Board of Trustees of the Federal Hospital Insurance Trust Fund* (1996).

FIGURE 5. SELECTED FEDERAL TRANSFERS: HYPOTHETICAL PROJECTIONS THROUGH 2050, BY DETERMINANTS OF SPENDING




SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of Economic Analysis; the Department of Labor, Bureau of Labor Statistics; the Health Care Financing Administration; the Social Security Administration; and Alan J. Auerbach, Jagadeesh Gokhale, and Laurence J. Kotlikoff as described in "Restoring Generational Balance in U.S. Fiscal Policy: What Will It Take?" *Economic Review*, Federal Reserve Bank of Cleveland, vol. 31, no. 1 (First Quarter 1995), pp. 2-12.

NOTES: General transfers are payments for unemployment insurance, food stamps, the earned income tax credit, Supplemental Security Income, pension benefit guaranty, veterans' life insurance, workers' compensation, military medical insurance, Black Lung benefits, and a category that mainly includes payments for nonprofit institutions, student aid, and medical services for retired military personnel and their dependents at nonmilitary facilities.

Health care transfers are payments for Medicare and the federal share of Medicaid.

The growth rate of additional medical costs is the difference between the growth rate of medical costs per person by age and sex and the growth rate of economywide compensation per hour. The word "additional" does not imply that medical costs are necessarily too high in any sense.

TABLE 2. AVERAGE ANNUAL GROWTH RATE OF COMBINED COSTS FOR MEDICARE AND MEDICAID, 1970-1995 (By fiscal year, in percent)

| | 1970-1975 | 1975-1980 | 1980-1985 | 1985-1990 | 1990-1995 |
|---|---|---|---|---|---|
| Payments per Enrollee | 11 | 16 | 13 | 7 | 8 |
| Compensation per Hour[a] | 8 | 9 | 6 | 4 | 3 |
| Additional Medical Costs per Enrollee[b] | 3 | 7 | 7 | 3 | 5 |

SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of Economic Analysis; and the Department of Labor, Bureau of Labor Statistics.

a. Nonfarm business sector.

b. The word "additional" describes the relation between the growth rates of payments per enrollee and compensation per hour. It does not imply that medical costs are necessarily too high in any sense.

also match HCFA's. (Both CBO and HCFA use the Social Security Administration's assumptions about population.)

*Social Security.* CBO treats Social Security (Old-Age, Survivors, and Disability Insurance) by breaking the program into estimated spending for three age groups: newborn through 18, 19 to 61, and 62 and older. Payments to people of those respective ages correspond substantially with benefits for surviving dependent children, the disabled, and retirees and surviving spouses. For convenience, the model refers to payments to those age groups as survivors', disability, and old-age benefits.

Unlike spending for general transfers and health care, which depend only on current factors, Social Security benefits depend on past wages as well as current prices. When Jane Doe retires at age 62 in 1997, her initial old-age benefits depend on the average of her best 35 years of earnings, which are indexed to a general measure of wage growth up to two years before retirement.[16] For instance, if she made $40,000 in 1985 and the economywide wage had grown by 25 percent between then and 1995, her earnings in 1985 would count as $50,000 toward her best 35 years of earnings. Her earnings in 1996 and 1997 can also count toward her best 35 years, but they are not indexed. After 1997, her nominal benefits grow at the rate of inflation as measured by the consumer price index (CPI), so her real benefits remain fixed at their initial level even as the economywide real wage grows. Similarly, survivors' and disability benefits initially depend on an average of past earnings that are indexed up to two years before the time of death or disability, then increase at the rate of CPI inflation.

CBO takes three steps to address the way in which past wages affect current spending, namely:

- o Constructing reference paths for the real wage and real spending;
- o Computing growth factors for real spending per person by age and sex in the reference path; and
- o Modeling the way in which differences from the reference path for the real wage cumulate as differences in real spending.

16. The model assumes that everyone retires at age 62, an assumption that has little effect on the results because benefits are actuarially adjusted. For example, compared with people who retire at age 65, those who retire at age 62 receive lower monthly benefits for a longer time. The Social Security Act sets the difference in monthly benefits so that the eventual cost (including interest) to the trust fund is about the same in either case.

The resulting model simulates consistent spending under base assumptions as well as under alternative assumptions for population or total factor productivity.

CBO's 10-year baseline projections of the real wage and real spending serve as the reference paths through 2007. CBO constructs the paths beyond then by assuming that those variables grow each year at the midpath rates projected by the Social Security Administration.[17]

CBO also estimates real spending per person by age and sex in 1996 and in each year of its 10-year baseline projections. The estimates depend on the age/sex profile for Social Security and on SSA's midpath projection of population. Those estimates enable CBO to deal separately with old-age, survivors', and disability benefits through 2007.

CBO then computes growth factors for real spending by age and sex. For example, suppose that in 2003 the projected real payment to the average 70-year-old woman is 2 percent higher than the payment in 2002 to the average woman who was then 70 years old. In that case, 1.02 is the growth factor in 2003 for payments to 70-year-old women. The growth factors implicitly reflect the way in which past and projected growth of the real wage affects real spending in the reference paths. Together with SSA's midpath population projection, the growth factors reproduce CBO's baseline real spending projections through 2007 and SSA's projected growth rates for real spending beyond then.[18]

After 2007, CBO treats Social Security spending as a whole in calibrating its model. Thus, the growth factor in any year (computed as described below) is the same for old-age benefits of everyone age 62 or older and for benefits of surviving dependent children and the disabled.

In modeling old-age benefits under its own economic specifications, CBO adopts the simplifying assumption that the hourly wage paid to people of every age and sex has grown and will grow each year at the same rate as the economywide wage. With that assumption, initial real benefits per new retiree increase each year at the same rate as the economywide real wage two years earlier. (For simplicity, this discussion ignores the two unindexed years.) In that case, each year's growth of

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17. Social Security Administration, *Annual Report*. That procedure ensures that CBO's simulation approximately accounts for the change (scheduled to be phased in) from 65 to 67 as the earliest age at which new retirees can draw full benefits.

18. The long-run nominal spending estimates of CBO and SSA differ mainly because they assume different rates of inflation: 2.7 percent for CBO and 4 percent for SSA. As a share of GDP, however, the two agencies' estimates of spending differ little through 2020—that is, until the cumulative effect of high deficits in the CBO simulation begins to exact its toll in earnest.

total real spending for people of each age and sex depends on two components: growth in the number of people of that age and sex, and growth of the real wage two years before their retirement.

Producing a base simulation beyond 2007 under CBO's economic specifications then requires defining how differences from the reference path in the growth of the real wage cumulate as differences in real spending. For example, suppose that in CBO's projections the real wage grows 1 percentage point faster than in SSA's projections in 2008 and 0.5 percentage points faster in 2009. That 1 percentage-point difference in 2008 affects the indexed earnings history and benefits of average 62-year-old men when they retire in 2010, and thus of 63-year-old men in 2011, 64-year-old men in 2012, and so on. They receive real per capita benefits that are 1 percent higher than those they would receive under SSA's real wage assumptions—in other words, 1.01 is the ratio of their real per capita benefits to the benefits they would receive under SSA's assumptions. Similarly, the cumulated 1.5 percentage-point difference in 2009 (the extra 1 percentage point in 2008 plus the extra 0.5 percentage points in 2009) appears in the indexed earnings history of average 62-year-old men when they retire in 2011, of 63-year-old men in 2012, and so on. In that case, the ratio of their real per capita benefits to the benefits they would receive under SSA's assumptions is 1.015. (Similar ratios would apply to women of those ages in those years.)

Following that reasoning, the growth of real old-age benefits paid to all 70-year-old men (OA70M), for instance, depends on three things:

- The growth factor for men of that age (QOA70M),
- The growth in the number of 70-year-old men (POP70M), and
- A ratio ($WRATIO_{-10}$) that reflects the cumulated percentage-point differ-ence from the reference path in the growth of the real wage 10 years earlier—two years before those men retired at age 62.

The resulting equation is:

$$OA70M/OA70M_{-1} = QOA70M*(POP70M/POP70M_{-1})*WRATIO_{-10}$$

Similar equations describe the growth of old-age benefits to other age and sex groups. Total real old-age benefits are then the sum of benefits paid to all men and women age 62 or older.

CBO follows the same general procedure for survivors' and disability benefits —using the reference path of real spending for each program to compute growth

factors, then modeling the way in which differences from the reference path in the growth of the real wage cumulate as differences in real spending. For a base case, CBO first constructs an exogenous index for each program that depends on its age/sex profile and on SSA's midpath projection of the population by age and sex. Such an index shows how total real spending would grow as the population grows and its composition changes, assuming that real spending for the average male and female of each age remains constant. A growth factor in any year in percentage terms is approximately 100 plus the difference between the growth rates of a program's reference spending and exogenous index. A program's growth factor implicitly reflects the influence of wage and price growth. Together, each program's growth factors and exogenous index reproduce reference spending.

For survivors' and disability benefits, an additional complication arises in modeling how differences from the reference path in the growth of the real wage cumulate as differences in real spending: unlike the newly retired, the newly surviving and disabled cannot all be assumed to enter the programs at the same age. Instead, CBO assumes that the proportions of people who have been enrolled in each program for a given period remain constant. By current estimates, 19 percent of survivors enrolled in the current year, 16 percent enrolled one year earlier, and so forth through 18 years earlier when 1 percent enrolled. As noted, real benefits depend on earnings history, which is indexed up to two years before entering the program. Thus, for instance, the real growth of survivors' benefits under CBO's base assumptions in 2020 depends on 19 percent of the cumulated percentage-point difference from the reference path in the growth of the real wage through 2018, 16 percent through 2017, and so forth through 1 percent in 2000.

In general, the growth of total real survivors' benefits (SU) depends on their growth factor (QSU), the growth of their exogenous index (JSU), and a so-called distributed lag of the ratio (WRATIO) that reflects past cumulated percentage-point differences from the reference path in the growth of the real wage, so that:

$$SU/SU_{-1} = QSU*(JSU/JSU_{-1})*[0.19*WRATIO_{-2} + 0.16*WRATIO_{-3} + \ldots]$$

For all components of Social Security spending, the growth rate of nominal benefits is approximately the growth rate of real benefits plus the inflation rate. The inflation rate that applies in the model after 2007 is not the rate for the CPI but the rate for the GDP price index. The model assumes that if the two price measures increase at different rates, the Congress will make nominal spending rise in line with indexed earnings and the overall price level. That assumption is optimistic because for the past 30 years the GDP price index has grown more slowly than the CPI by an average of 0.4 percentage points a year.

To allow for alternative assumptions about population and total factor productivity, CBO's model uses the same methods to specify Social Security spending through 2007. For an alternative assumption about population, CBO recomputes the exogenous indexes for survivors' and disability benefits (the alternative population assumption directly enters the equations for old-age benefits). Together with the programs' growth factors, the recomputed indexes and the old-age equations imply that each program's real spending per person by age and sex would remain at its base level if the real wage remained at its base level. The equations then cumulate percentage-point differences in the growth of the real wage from CBO's economic baseline through 2007 and from SSA's projections beyond then. That method enables the model to reproduce CBO's base spending under base assumptions and generate consistent spending under alternative assumptions. Differences in the size and composition of the population immediately affect total Social Security spending, but differences in the growth of the real wage take time to be fully phased into benefits.

*Retirement and Veterans' Benefits.* A variety of methods are used to simulate spending for retirement and veterans' benefits. For civilian and military retirement, CBO calibrates the model using spending projections by the Office of Personnel Management (OPM) and the Department of Defense (DoD), then adjusts spending to correspond to CBO's economic specifications and assumptions. (The method of calibration and adjustment resembles that used for survivors' and disability benefits in Social Security.) CBO extends a forecast by the Railroad Retirement Board to project Railroad Retirement benefits and uses data from the Department of Veterans Affairs to project spending for veterans' benefits.[19]

In modeling spending for civilian retirement, the phaseout of the Civil Service Retirement System (CSRS) complicates matters. About half of federal workers remain in CSRS, but since 1983 all new workers have been enrolled in the Federal Employees' Retirement System (FERS) instead. The two plans have different rules about the benefits they will pay based on age, earnings history, and length of service. As time passes, more and more workers will retire under the provisions of FERS rather than CSRS. Because the benefits paid under the two plans differ, the age/sex profile for civilian retirement will change every year.

Calibrating CBO's model to OPM's projection of growth in spending for civilian retirement after 2007 requires three steps:

19. U.S. Railroad Retirement Board, *Annual Actuarial Report* (1996).

- o Extending the detailed OPM projection beyond 2030 by assuming that total nominal spending continues to grow at 3.2 percent a year (OPM's projected rate in 2030);

- o Constructing an exogenous index for spending that depends on the number of retirees, using interpolated data from OPM that show how the ratios from the age/sex profile change each year; and

- o Applying the method used for survivors' and disability benefits by estimating the proportions of recipients who have received retirement benefits for a given number of years—assuming that federal civilian workers retire at age 56 and imposing projected mortality rates on respective age cohorts—and then basing initial benefits on the three best (last) years of earnings.

For military retirement, the procedure is simpler because there is no phase-in of a new pension system and DoD's projection extends through 2068. In calibrating the model, CBO assumes that military personnel retire at age 45.

For Railroad Retirement, CBO scales the 25-year projection of the Railroad Retirement Board in line with CBO's specifications and assumptions. From 2020 on, total real benefits are assumed to grow at 2.1 percent a year.

For veterans' benefits, CBO assumes that spending per beneficiary—about $4,700 in 1993—increases at the rate of inflation. Projecting the number of veterans receiving benefits involves three steps:

- o Finding the number and average year of birth of beneficiaries who are veterans of each war (for example, there are 692,000 recipient veterans of World War II, whose average year of birth is 1922; 191,000 recipient veterans of the Korean War, whose average year of birth is 1931; and so forth);

- o Applying projected mortality rates each year for men in such birth cohorts to estimate the total number of recipients through 2030; and

- o Assuming that after 2030 the number of recipients declines at a rate of 3.4 percent a year (the rate calculated for 2030).

*Other Grants, Foreign Transfers, and Net Subsidies.* The model separates other grants (those other than for Medicaid) and foreign transfers into their mandatory and discretionary parts. Today, about 80 percent of other grants and 70 percent of foreign transfers are discretionary. Net subsidies are treated as mandatory. Mandatory

spending grows with net national product; discretionary spending, either with net national product or at the rate of inflation, depending on the budget rule.

Consumption Expenditures. The model splits federal consumption into its defense and nondefense components—respectively, about 66 percent and 34 percent. Around 90 percent of each component is now discretionary.

Through 2007, CBO's baseline projections determine the values for all components of federal consumption. After 2007, mandatory consumption grows with net national product; discretionary consumption, with net national product or at the rate of inflation, depending on the budget rule.

Total federal consumption has fallen as a share of output in the past, largely because the defense share has followed a declining trend since the Korean War (see Figure 6). That downward trend in consumption's share of GDP would halt if discretionary spending grew with net national product but would intensify if such spending grew only at the rate of inflation.

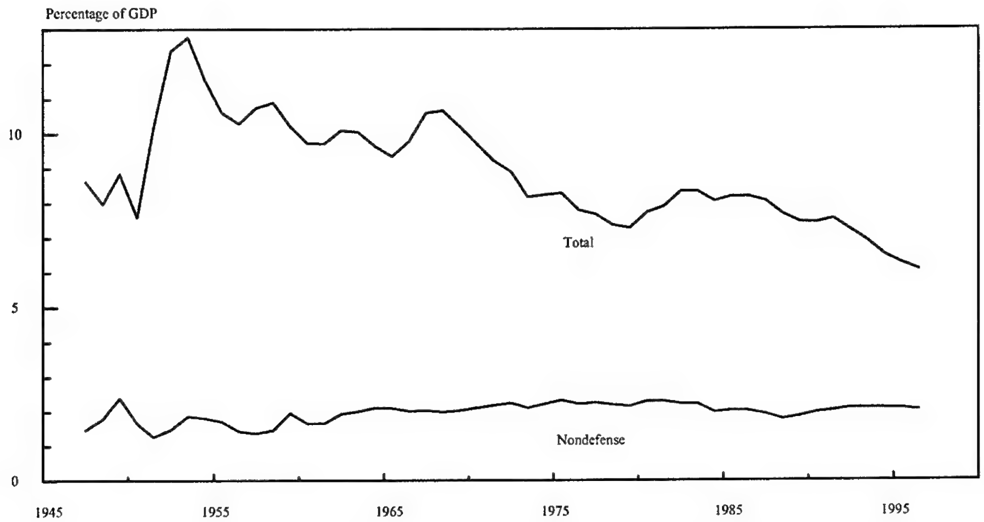
Net Interest. Net interest is the difference between interest paid by the government and interest received on government loans. Interest received grows in the model at the same rate as net national product. Interest paid depends on the amount, age, and type of debt and on past and current interest rates.[20] The amount and age of debt at the end of each year is determined by debt at the start of the year (old debt) plus new debt issued.

In CBO's model, the type of debt is defined by its term when issued: short (six-month bills), medium (five-year notes), or long (30-year bonds). Each year, all six-month bills mature, 20 percent of five-year notes mature, but—for practical purposes—no 30-year bonds do. On average, old bills mature and are reissued at the end of the first quarter of the year; old notes, at the end of the first half. New debt is then issued in the following proportions: 5 percent as bonds, about 40 percent as bills (the ratio varies because bills are issued at a discount, so the amount issued depends on the interest rate), and the rest as notes. New debt is assumed to be issued in the middle of the year.

Interest paid then depends on the amounts of old, reissued, and new debt and on their effective rates of interest. The effective rate for old notes is the total amount of interest paid on notes in the previous year as a percentage of the total value of notes at the start of that year. For reissued and new notes, the effective rate is the current

20. See Congressional Budget Office, *Federal Debt and Interest Costs*, pp. 101-104.

FIGURE 6. FEDERAL CONSUMPTION EXPENDITURES




SOURCE: Congressional Budget Office based on data from the Department of Commerce, Bureau of Economic Analysis.

note rate. Matured, reissued, and new notes are assumed to pay interest for six months (because, on average, old notes mature and are reissued, and new notes are issued, in the middle of the year). Bonds and bills are treated similarly, except that bonds are assumed never to mature, and old bills pay interest for only three months at the previous year's rate (they then mature); reissued bills pay interest for nine months at the current rate. Interest paid on each type of debt is then calculated by multiplying its amount times its effective rate times the fraction of the year that it pays interest. Total interest paid is the sum of interest paid on each type of debt.

Receipts. Other things being equal, all federal taxes in CBO's model grow at the same rate: the average of the growth rates of net national product and net domestic product. That formulation reflects the fact that foreigners typically pay tax on their U.S. earnings from direct, but not indirect, investment. Thus, the model uses as a fundamental tax base the net income of the economy after allowing for tax treaties.

Beyond that basic formula, two factors come into play for NIPA personal tax and nontax revenues. First, the share of income paid as tax depends in part on the share received as interest on the federal debt. Such interest income is part of the tax base even though it is not part of net product. Second, CBO assumes that premiums that the government receives for Medicare Part B equal a fraction of the outlays for that program—14 percent in 2007 and thereafter.

Other Items. As noted earlier, the difference between the NIPA deficit and the change in debt held by the public arises from three components: net federal investment, other items that reconcile the NIPA and unified deficits, and other means of financing. Net investment equals gross federal investment minus depreciation of federal capital. CBO's model splits real gross investment into its defense and nondefense sectors, whose respective shares after 2007 are 28 percent and 72 percent. In both sectors, mandatory gross investment—now about 10 percent of total federal investment—increases in the model at the same rate as net national product. Discretionary investment grows either at the same rate as net national product or at the rate of inflation (depending on the budget rule). Depreciation is the sum of the previous year's stock of each type of federal capital times its depreciation rate. The other two components—reconciliation items and other means of financing—increase in the model at the same rate as net national product.

## Making a Budget Simulation Under Alternative Assumptions

CBO examined how the model's outcome depends on different assumptions for population and total factor productivity. An alternative population projection enters the model directly through the equations for old-age benefits and indirectly through the exogenous indexes for total labor hours and for various transfer programs. CBO

uses the alternative population projection to recompute those indexes. Given the multiplicative adjustment factors for the indexes, the recomputations ensure that hours worked per person by age and sex remain as they were in the base case. Benefits per person by age and sex would also remain as they were in the base case if other things did so as well. Alternative assumptions for TFP enter the model directly through the Cobb-Douglas production relation in the nonfarm, nonhousing business sector.

As with a base case, the budget rules under alternative assumptions differ between the medium and long term. To allow for how the budget process works, some budget components obey their (adjusted) equations through 2007, but others do not. After 2007, all components respond to economic and demographic factors in accord with their equations.

<u>Budget Rules in the Medium Term</u>. Through 2007, budget components may respond to economic and demographic factors, to demographic factors alone, or to no factors at all. Some budget components obey their equations (subject to adjustments) and therefore depend on economic factors. For instance, tax revenues and Social Security spending rise or fall with income and earnings histories. Such components respond indirectly to population and total factor productivity: to population because it feeds directly into the workforce and hence indirectly into output, revenues, debt, capital, wage and interest rates, and so on; and to total factor productivity because it feeds directly into output, and so on. (Social Security benefits also depend directly on the age and number of recipients.)

Economic factors do not affect other budget components. For some transfers, payments per person by age and sex are set at their baseline values; medium-term spending for those programs depends only on the age and number of recipients. For the remaining components, spending through 2007 is set at its baseline level and is independent of any alternative assumption.

Specifically, CBO assumes for the medium term that:

o General transfers per person by age and sex are set by CBO's baseline budget projections, and spending depends directly on population, but not on economic variables.

o Health transfers per person by age and sex are set by the baseline projections, and spending depends directly on population but not on economic factors.

- o Social Security benefits per person by age and sex depend on earnings history, in accord with their equations, and outlays depend directly and indirectly on population and indirectly on total factor productivity.

- o Civilian and military retirement benefits depend on earnings history, as their equations specify, and spending depends indirectly on population and TFP. (Benefits, however, do not respond directly to differences in population.)

- o Railroad Retirement and veterans' benefits are set by the baseline projections, and outlays do not respond to any alternative assumption.

- o Other grants, foreign transfers, and net subsidies are set by the baseline projections, and spending does not change under any alternative assumption.

- o Federal consumption and investment are set by the baseline projections, and spending does not change under any alternative assumption.

- o Net interest depends on interest paid minus interest received, both of which obey their equations. Interest paid depends on the debt, debt structure, and interest rates; interest received, on net national product. Both payments and receipts respond indirectly to population and total factor productivity.

- o Tax receipts, as their equations specify, depend on output and the tax rates implicit in the baseline projections, and revenues depend indirectly on population and TFP.

- o Reconciliation items and other means of financing maintain their respective baseline shares of NNP, as their equations specify, and depend indirectly on population and TFP.

Those budget rules are somewhat arbitrary, but CBO adopts them partly because they roughly depict the way the budget process works and partly because they make the outlook more optimistic than it would be otherwise. (The treatment of retirement and veterans' benefits simply makes the model more tractable.) When economic factors change, spending for many programs does not automatically respond at once. Instead, the Congress must act to bring spending into line with new conditions, and it usually does so only after some time has passed. In addition, the budget rules make it more likely that good luck will prevent runaway deficits. For example, higher output immediately raises tax receipts but not spending for consumption and investment, thereby reducing the deficit more than it would if that spending rose at the same time as output.

Depending on the budget rules, alternative assumptions for population and total factor productivity affect the budget through various channels (see Table 3). For instance, the effect of higher population depends on whether it comes from a higher retirement-age or working-age population. With more retirees (other things being equal), transfers rise. That raises the deficit and interest rates and leads to less private investment and therefore less output and lower wages. The lower wages gradually feed into earnings histories, indirectly reducing spending for Social Security and federal retirement and slightly moderating the rise in the deficit. Federal consumption and investment remain at base levels, but net interest rises with interest rates and debt, further raising the deficit.

The process works in reverse if there are more workers. Then (other things being equal), output and revenues rise, reducing the deficit and interest rates, boosting private investment, and further raising output and income.

Higher total factor productivity in the model reduces the deficit but raises the interest rate. Specifically, the higher TFP raises output and revenues and thereby reduces the debt. A lower debt increases the supply of capital, but higher output increases the demand for capital. In the model, the increase in supply is mitigated by reduced rates of private saving and net capital inflows, so the greater demand outweighs the greater supply and the interest rate rises. Thus, debt initially falls below its base level but accumulates at a higher interest rate.

Budget Rules in the Long Term. After 2007, the budget equations determine the growth of spending and revenue, and all budget components (except Railroad Retirement and veterans' benefits) respond to real economic factors. For instance, spending per person by age and sex for general transfers will grow in the long run at the same rate as net national product per worker-hour.

Those long-term rules partly offset the medium-term effect that an alternative assumption for population or TFP has on the debt-to-output ratio. For example, other things being equal, a population with more workers in the medium term drives the debt-to-output ratio below its base level: output and revenues rise and interest rates fall, while most spending remains at its base level or rises only gradually with earnings histories. In the long run, however, all major (mandatory) spending components grow in line with output and productivity, thereby partly offsetting the favorable effect of higher output on the deficit and debt. In the case of higher TFP, higher long-run spending combines with higher interest rates to put upward pressure on the debt. The ultimate results depend on the likelihood that favorable outcomes for the population or total factor productivity will overcome those offsetting factors and prevent runaway deficits.

TABLE 3. PRINCIPAL INFLUENCES ON SIMULATED FEDERAL SPENDING AND REVENUES UNDER ALTERNATIVE ASSUMPTIONS FOR POPULATION AND PRODUCTIVITY, BY BUDGET CATEGORY

| | Through 2007 | | After 2007 | |
|---|---|---|---|---|
| | Alternative Population | Alternative Total Factor Productivity | Alternative Population | Alternative Total Factor Productivity |
| Transfers, Grants, and Net Subsidies | | | | |
| General transfers | enrollees | none | enrollees | NNP per hour |
| Health care | enrollees | none | enrollees | medical costs[a] |
| Social Security | enrollees | wages | enrollees | wages |
| Retirement and veterans' benefits | | | | |
| Civilian retirement | wages | wages | wages | wages |
| Military retirement | wages | wages | wages | wages |
| Railroad Retirement | none | none | none | none |
| Veterans' benefits | none | none | none | none |
| Other grants, foreign transfers, and net subsidies | none | none | NNP[b] | NNP[b] |
| Consumption Expenditures | none | none | NNP[b] | NNP[b] |
| Net Interest | interest rates | interest rates | interest rates | interest rates |
| Receipts | NNP/NDP | NNP/NDP | NNP/NDP | NNP/NDP |
| Net Investment[c] | none | none | NNP[b] | NNP[b] |
| Reconciliation Items[d] | NNP | NNP | NNP | NNP |
| Other Means of Financing[e] | NNP | NNP | NNP | NNP |

SOURCE: Congressional Budget Office.

NOTE: NNP = net national product; NDP = net domestic product.

a. The growth rate of medical costs per person by age and sex depends on the growth rate of economywide compensation per hour.

b. Mandatory spending grows at the same rate as NNP; discretionary spending grows either at the same rate as NNP or at the rate of inflation.

c. Gross federal investment minus depreciation of federal capital.

d. Items other than net investment that reconcile the unified budget deficit with the national income and product accounts deficit.

e. Means of financing such as revenues from the selling of assets or the coining of money.

## ESTIMATING THE EFFECTS OF UNCERTAINTY ABOUT PRODUCTIVITY AND POPULATION

Because assumptions about total factor productivity and population strongly influence the outcome of the model, CBO examined the effect of uncertainty in those key exogenous variables. Exogenous variables affect, but remain unaffected by, the budget and economy. Thus, they can be determined by equations that are independent of the budget and the economy. Analysts can estimate the degree of uncertainty in such equations to see how it leads to uncertainty in the results of the model.

To take a simple example, suppose population had not grown for a very long time. Births and deaths varied every year but offset each other on average; growth over some periods balanced decline over others. In an average year, 22 of every 1,000 30-year-old women had a baby, and 12 of every 1,000 60-year-old men died. A population forecast could then project births and deaths each year using such averages.

That method predicts the most likely outcome based on history, but it fails to show how uncertain such a projection is. Even if each projected average is correct, there will not be exactly 22 babies born each year for every 1,000 30-year-old women; there may be 23 one year and 21.5 the next. More important, the projected averages themselves may not be exactly right; the death rate for 60-year-old men may turn out to average 11.5 per 1,000 or 12.6 per 1,000. Errors in predicting birth and death rates will feed into the model's economic and budget simulations by affecting the projected growth in the number of workers and recipients of transfers. Even in this simple example, uncertainty about population leads to uncertainty about economic and budgetary outcomes.

Analysts can estimate the degree of uncertainty in outcomes that arises from uncertainty about exogenous variables by using statistical methods. That approach specifies exogenous variables by stochastic equations—that is, equations that are statistically estimated based on historical data and that add or subtract a random number each year. In the simple case above, a stochastic equation for the number of births in any year for every 1,000 30-year-old women would simply predict 22 births plus or minus a random number. Those random numbers would average to zero over an infinite time span—in other words, their expected value is zero. In a finite span, the numbers need not average to zero, although the longer the span, the closer to zero the average is likely to be.

Not every random number is equally probable. For instance, a value of +1 (implying 23 births) is more likely than a value of -3 (implying 19 births). The likely dispersion of random numbers is estimated along with the stochastic equation and

expressed as a standard deviation. For example, given the familiar bell-shaped (normal) curve, a random number has two chances in three of falling within one standard deviation of its expected value (in this case zero) and 95 chances in 100 of falling within two standard deviations of its expected value. That is, two-thirds of outcomes will span a range of two standard deviations (the expected value plus or minus one standard deviation), and 95 percent of outcomes will span a range of four standard deviations.

With expected values and standard deviations, analysts can assess uncertainty by drawing repeated random samples to make stochastic forecasts. For example, suppose an analyst needs to predict the number of babies born to 30-year-old women for the next 20 years. In this case, for every 1,000 women a stochastic forecast for each year would predict 22 births plus or minus a random number. The random numbers are found by drawing a sample of 20 random numbers from a distribution with an expected value of zero and the historically estimated standard deviation. None of the random numbers are likely to be exactly zero, and because 20 is a small sample, their average is likely to differ from zero. If the process is repeated many times, however, the average of all of the samples of 20 will probably be close to zero. Thus, the average of many stochastic 20-year forecasts will be close to the most likely outcome, and the dispersion of those forecasts will indicate the degree of uncertainty about the outcome. For instance, the probability that every 1,000 30-year-old women will have an average of more than 23 babies a year is simply given by the proportion of stochastic forecasts for which that is true.

Of course, the estimate of uncertainty depends on the underlying statistical model and is itself uncertain. Nevertheless, for a given model, this approach gives the best estimate of the degree of uncertainty in the forecast.

### Total Factor Productivity

Simulated TFP comes from an equation that CBO estimated for the years from 1948 to 1996. The equation predicts growth of 1 percent a year, roughly the average rate since 1959. CBO examined more complicated equations that relate the current growth rate of TFP to its growth rate(s) in the previous year(s). But the equation that best represents the data, according to standard criteria, predicts that total factor productivity will increase by 1 percent a year, regardless of its previous growth.[21] Of course, that equation is far from exact; TFP has not risen at a constant rate of 1

21. See H. Akaike, "Fitting Autoregressive Models for Prediction," *Annals of the Institute of Statistical Mathematics*, vol. 21 (1969), pp. 243-247; and G. Schwarz, "Estimating the Dimension of a Model," *The Annals of Statistics*, vol. 6 (1978), pp. 461-464.

percent a year, and it will not do so in the future. The analysis simply finds that history indicates no clearly better prediction than 1 percent a year.

The equation for TFP implies a standard deviation for annual growth of 2 percentage points. That is, there are two chances in three that growth in any year will fall within a range of -1 percent to 3 percent (the expected 1 percent plus or minus 2 percentage points). But that range overstates the likely variation of average TFP growth over a number of years—two bad years in a row are much less likely than any one bad year. Therefore, as the number of years increases, the range of variation in average growth narrows—rapidly at first, then ever more gradually. Using 750 stochastic simulations, CBO estimated that the standard deviation of average growth in TFP is about 0.5 percentage points a year through 2010, more than 0.3 percentage points a year through 2030, and nearly 0.3 percentage points a year through 2050.

As with behavioral variables, the samples of random numbers drawn for exogenous TFP growth are adjusted so that their average matches CBO's baseline economic projections each year through 2007. No single sample matches, but the average of 750 samples matches. After 2007, no adjustments are imposed. Thus, in the average adjusted sample, TFP grows at an average rate of 0.6 percentage points a year through 2007 (the baseline average) and at 1 percent a year thereafter.

## Population

To represent uncertainty about future population, CBO used a sample of 750 stochastic population forecasts provided by Professors Ronald D. Lee of the University of California at Berkeley and Shripad Tuljapurkar of Stanford University.[22] In their model, which is far more complex than the simple example described above, fertility and mortality rates eventually lead to a nearly stable population. (For net immigration, they use the midpath projections of the Census Bureau.) Fertility rates were modeled so that the expected number of children that the average woman bears in her lifetime eventually stabilizes at 2.1. That lifetime fertility rate would keep the population stable if mortality rates were stable. Although average mortality rates by age and sex were modeled to continue to decline at constant rates, they eventually fall slowly enough that the population becomes nearly stable. (The Social Security Administration's midpath projection also assumes that the population eventually becomes nearly stable.)

22. Ronald D. Lee and Shripad Tuljapurkar, "Stochastic Population Forecasts for the United States: Beyond High, Medium, and Low," *Journal of the American Statistical Association*, vol. 89, no. 428 (December 1994), pp. 1175-1189.

The average stochastic population has higher fertility rates and lower mortality rates than SSA's midgrowth population. After about 2020, the larger birth cohorts of the average stochastic population enter the workforce, making its simulated labor hours grow faster than in SSA's middle path (see Table 4). But from the start, the lower mortality rates of the average stochastic population yield a higher old-age dependency ratio (the population age 65 or older as a percentage of the population age 20 to 64). The unfavorable budgetary effects of a higher dependency ratio more than offset the favorable effects of faster growth in labor hours, so the average stochastic population would lead to a higher debt-to-output ratio than SSA's midgrowth population.

Moreover, the stochastic populations suggest that SSA's high- and low-growth population paths do not fully describe the possible range of outcomes.[23] By 2020 (and increasingly thereafter), simulated labor hours in the SSA high and low paths span a range that covers less than two-thirds of the stochastic outcomes—that is, the average stochastic outcome plus or minus about one standard deviation. For instance, the index of labor hours in 2030 for the upper bound of the range that covers two-thirds of stochastic outcomes is higher than that for the SSA high path (126.5 versus 123.3), and the index for the lower bound is less than that for the SSA low path (109.9 versus 113.0). For the old-age dependency ratio, SSA's high and low paths span a range about as great as that of two-thirds of the stochastic populations. Loosely speaking, the analysis of Lee and Tuljapurkar suggests that if SSA's middle path represented the best estimate of future population, a range about twice as great as that spanned by the SSA high and low paths would be needed to encompass 95 percent of possible outcomes.

CBO modified the stochastic population projections so that the results from using them in its model are directly comparable with those from using the SSA populations (see Box 1). As modified, the average stochastic population by age and sex increases at the same rate as in SSA's middle path, a result that makes the stochastic populations more optimistic than their unmodified counterparts. Thus (at least by the analysis of Lee and Tuljapurkar, and accepting other assumptions), the stochastic results reported for CBO's model understate the probability of adverse outcomes in the absence of policy action.

23. SSA's high-growth path is relatively favorable for the Social Security trust funds; it has high rates of fertility, mortality, and net immigration, which yield high labor hours and a low old-age dependency ratio. SSA's low-growth path assumes low values for those demographic rates.

TABLE 4. DISPERSION OF SIMULATED LABOR HOURS AND PROJECTED OLD-AGE DEPENDENCY RATIOS

| | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|
| | **Simulated Labor Hours (Index, 1996=100)** | | | | | |
| SSA Populations | | | | | | |
| High growth | 104.6 | 114.2 | 119.0 | 123.3 | 130.9 | 138.4 |
| Midgrowth | 104.1 | 112.6 | 116.1 | 117.6 | 120.8 | 122.6 |
| Low growth | 103.7 | 111.3 | 113.7 | 113.0 | 112.3 | 108.9 |
| Stochastic Populations[a] | | | | | | |
| Upper bound[b] | 105.1 | 113.1 | 119.5 | 126.5 | 138.7 | 153.5 |
| Average | 105.0 | 112.7 | 116.0 | 118.0 | 122.9 | 127.8 |
| Lower bound[b] | 104.9 | 112.3 | 112.7 | 109.9 | 107.2 | 103.5 |
| | **Projected Old-Age Dependency Ratios (Percent)[c]** | | | | | |
| SSA Populations | | | | | | |
| High growth | 20.8 | 20.6 | 25.7 | 32.1 | 31.7 | 30.4 |
| Midgrowth | 21.0 | 21.4 | 27.5 | 35.5 | 36.8 | 37.0 |
| Low growth | 21.2 | 22.2 | 29.1 | 38.9 | 42.7 | 45.7 |
| Stochastic Populations[a] | | | | | | |
| Upper bound[b] | 21.2 | 21.4 | 26.6 | 34.2 | 35.0 | 33.6 |
| Average | 21.3 | 21.9 | 27.7 | 36.8 | 39.4 | 39.7 |
| Lower bound[b] | 21.5 | 22.3 | 28.9 | 40.0 | 45.4 | 49.4 |

SOURCE: Congressional Budget Office based on population projections from the Social Security Administration and from Ronald D. Lee and Shripad Tuljapurkar, "Stochastic Population Forecast for the United States: Beyond High, Medium, and Low," *Journal of the American Statistical Association*, vol. 89, no. 428 (December 1994), pp. 1175-1189.

NOTE: SSA = Social Security Administration.

a. The stochastic populations are 750 projections that depend on a statistical model of population dynamics. According to the population model, the average of the projections represents the most likely forecast, and the dispersion of the projections represents the uncertainty about the most likely forecast.

b. Upper and lower bounds bracket two-thirds of the stochastic outcomes, so that one-sixth of outcomes lie above the upper bound and one-sixth lie below the lower bound.

c. The old-age dependency ratio is the population age 65 or older as a percentage of the population age 20 to 64.

BOX 1.
MODIFYING THE STOCHASTIC POPULATION PROJECTIONS

The Congressional Budget Office (CBO) modified the sample of stochastic population forecasts to use them in its economic model. The forecasts cover five-year age groups of each sex and are made for every fifth year. (In other words, the forecasts estimate the male and female populations that are newborn through age 4, age 5 to 9, and so on through age 105 and older for 1995, 2000, and so on through 2070.) CBO used linear interpolations of logarithms to construct the corresponding population series by single year starting in 1990.[1]

CBO also recentered the stochastic population forecasts to make the results directly comparable with those of the Social Security Administration's (SSA's) forecasts. Recentering involved:

- Finding the average number of people in each age/sex group in every year of the interpolated stochastic populations;

- Calculating the ratios of those average numbers to the respective numbers in SSA's mid-growth population forecast; and

- Dividing the respective numbers in each stochastic population by those ratios.

That method aids comparison with the SSA midgrowth projection and preserves some, but not all, of the relations among variables in the stochastic populations. The recentered populations by age and sex increase at the same average rate as in SSA's midgrowth path. And differences in growth rates among age and sex groups remain the same between stochastic populations. For instance, if the growth rates for 15-year-old males in 2000 differ by 1 percentage point in two uncentered populations, they also differ by 1 percentage point in the corresponding recentered populations. Similarly, the growth rates in a given year for 15-year-old males and 40-year-old females differ by the same amount in an uncentered and the corresponding recentered population.

But recentering affects implied fertility and mortality rates, which are fundamental relationships in the population model. Consequently, the results from the recentered stochastic populations cannot be taken literally. Instead, they represent hypothetical projections with the same average values as the SSA mid-growth projection and the same dispersion around the average as the uncentered stochastic projections.

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1. Because the levels of some subpopulations by age peak around 1995, interpolation by cubic splines generates implausibly wide swings in growth rates in the critical initial years of the forecasts.